In-Situ Anomaly Resolution Research

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Ames Human-Computer Interaction Group

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in collaboration with
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Funded by Engineering for Complex Systems

HCI Group

- Research Areas
  - Human Performance Modeling
  - Mixed Initiative Planning
  - Anomaly Resolution
- Research is grounded in mission applications through an iterative design and development process

Background

- Ames HCI Group engaged to improve utility and usability of Investigation Organizer (Columbia, Contour, Air Show Mishap)
- ECS proposed pushing research upstream from mishaps and investigations to anomalies

Opportunity

- Request to
  - Conduct user research before a tool is proposed or implemented
  - Design a tool based on user research and guide implementation
- Access across sensitive anomaly resolution contexts
- Relevant to NASA and other organizations that have anomalies, incidents and investigations

Research Plan

- Background research
  - Anomaly/Investigation reports, related work
- **Retrospective interviews**
- **Conduct In-situ observations of anomaly resolution**
  - **MER Spirit Anomaly**
  - **Gravity Probe B**
  - **SOFIA**
  - Hubble?
- Iteratively prototype anomaly resolution support tools
- Collect tool usage metrics for existing processes and the new tool

Data Collection Goals

- To systematically gather and integrate anomaly resolution data across NASA missions and centers:
  - Base-line current anomaly resolution practices
  - Identify problems, workarounds, and areas of opportunity feeding requirements for processes or tools supporting anomaly resolution

In-Situ Observation Methods

- Semi-structured note taking

Code	Description
CUL	**Cul**ture (e.g. hierarchical vs. egalitarian)
M	**M**ode of work (individual vs. collaborative)
P	**P**rocess, information flow, emergent conventions (explicit vs. implicit)
ROL	**R**oles people play
INT	**Int**erruption level (low vs. high)
D	**D**ecision making
R	**R**isk
T	**T**echnology and task (discussion using projector)
B	**B**reakdowns observed
O	**O**ther

- Photos
- Work Products

Data Collection Contexts

- Mars Exploration Rovers
  - operations phase: 45 hours
- Gravity Probe-B
  - operations phase: 120 hours (so far)
- SOFIA Infrared Observatory
  - design/test phase: 35 hours (so far)

Mars Exploration Rovers

- Robotic geologists searching for evidence of a watery past on Mars
- Observed: sol 18 Anomaly
  - Initially manifested itself as missed communication passes attributed to bad weather at Canberra AU DSN Station
  - Eventually identified as vehicle locked in repeating reset loop
  - Resolved as software memory management condition and corrected by file deletion, flight software changes and memory management flight rules

Gravity Probe B

- Experiment to measure Earth's distortion of time/space, and the "frame-dragging effect"
- "the most challenging experiment that NASA will perform in this millennium," according to Dr. Frank McDonald, former NASA chief scientist
- Observed: multiple anomalies

SOFIA

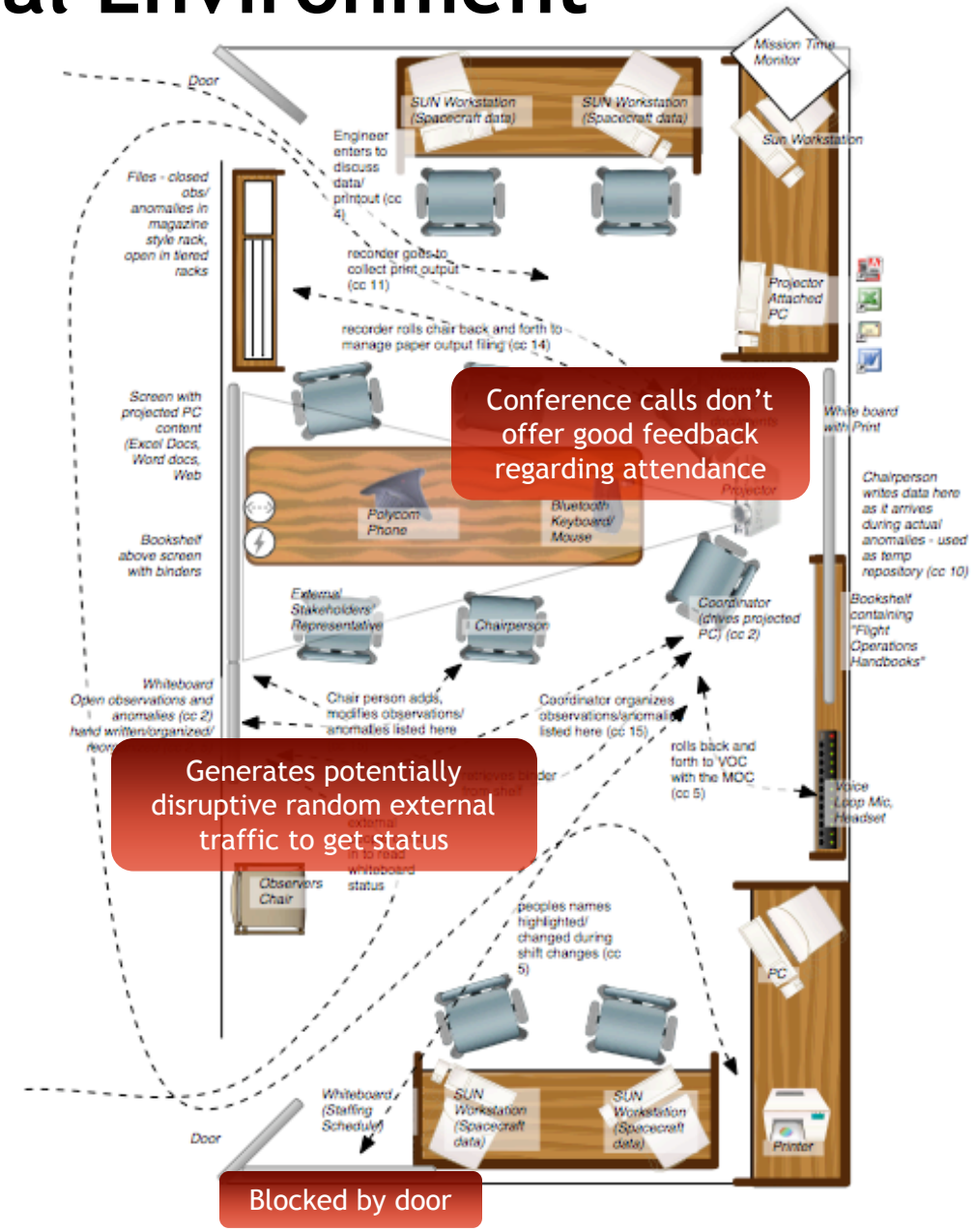
Stratospheric Observatory for Infrared Astronomy

- Boeing 747SP aircraft modified to accommodate a 2.5 meter reflecting telescope.
- SOFIA will be the largest airborne observatory in the world.
- Observed: multiple tests

Data Analysis Method

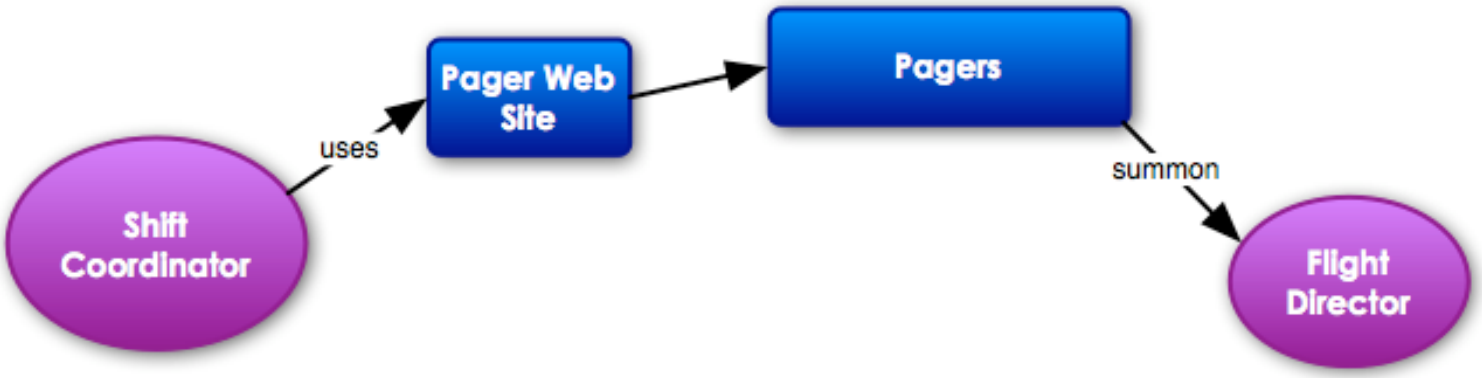
- Contextual Inquiry (Beyer & Holtzblatt) adapted to capture data in model form
  - Physical Environment
  - Work Flow
  - Sequence of Events
  - Work Products/Artifacts

Physical Environment

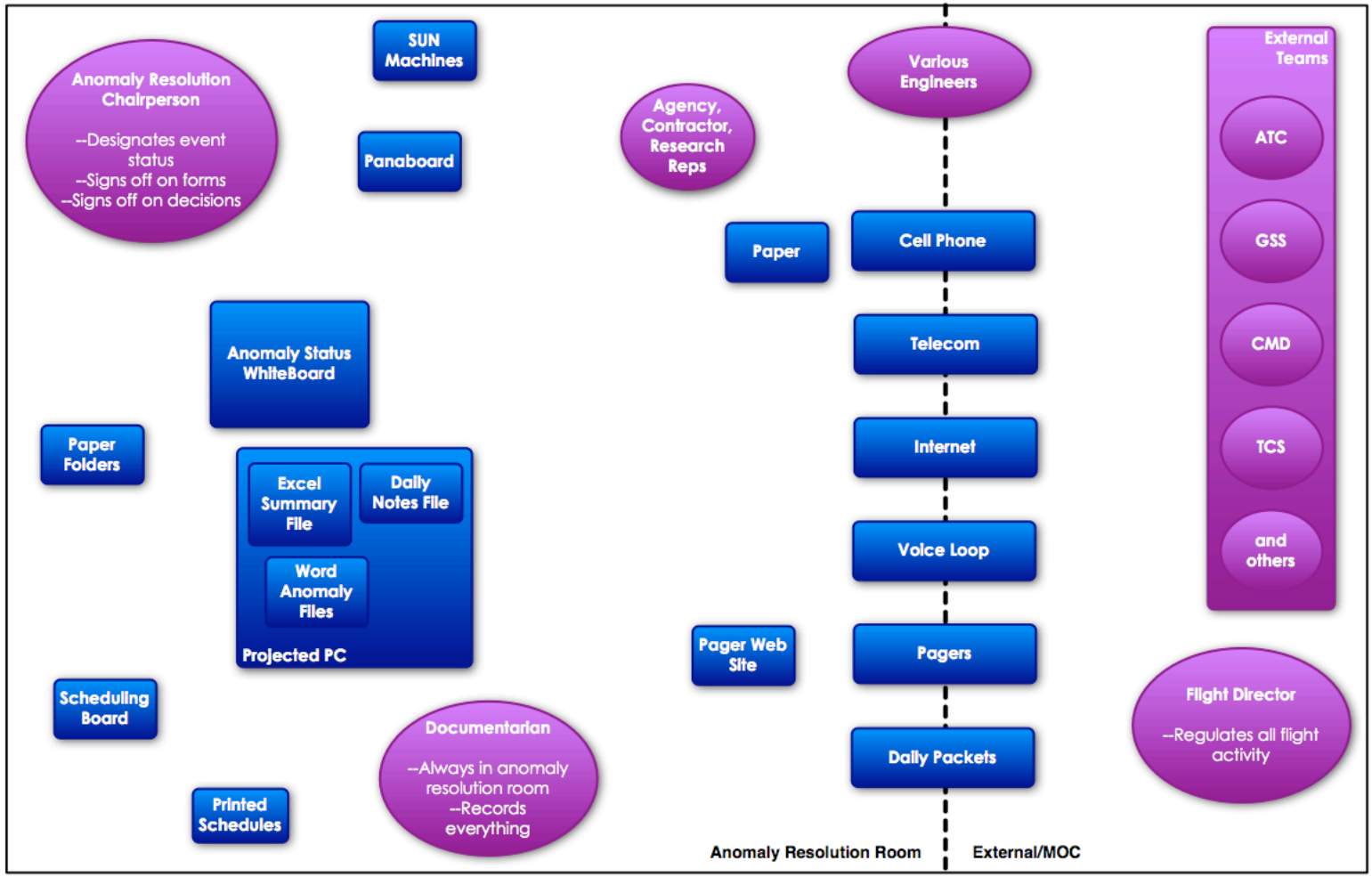


Work Flow

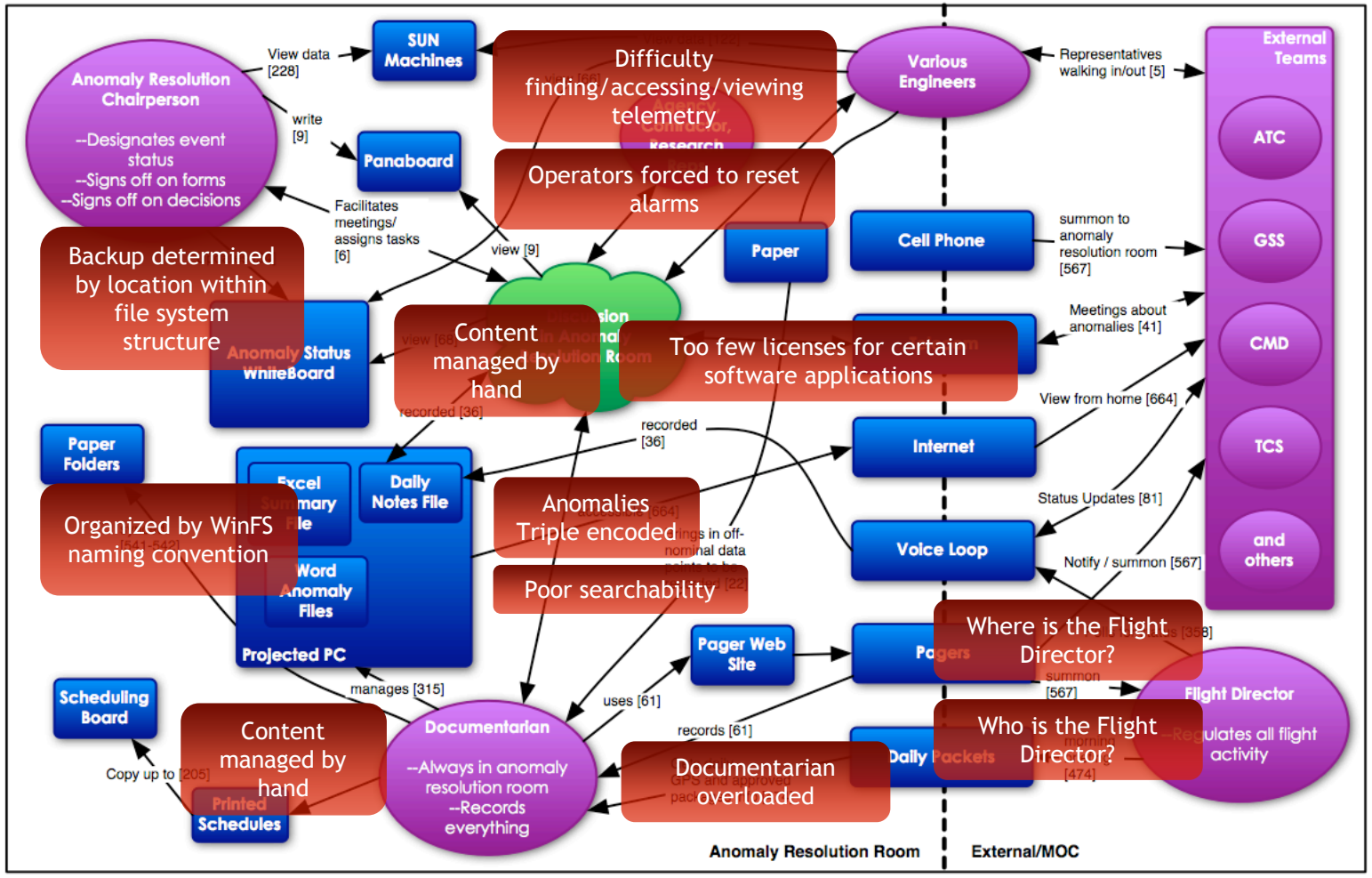
- Demonstrates Work Flow Processes
- Arrows denote actions or flow of information between objects/actors



Tools and Media



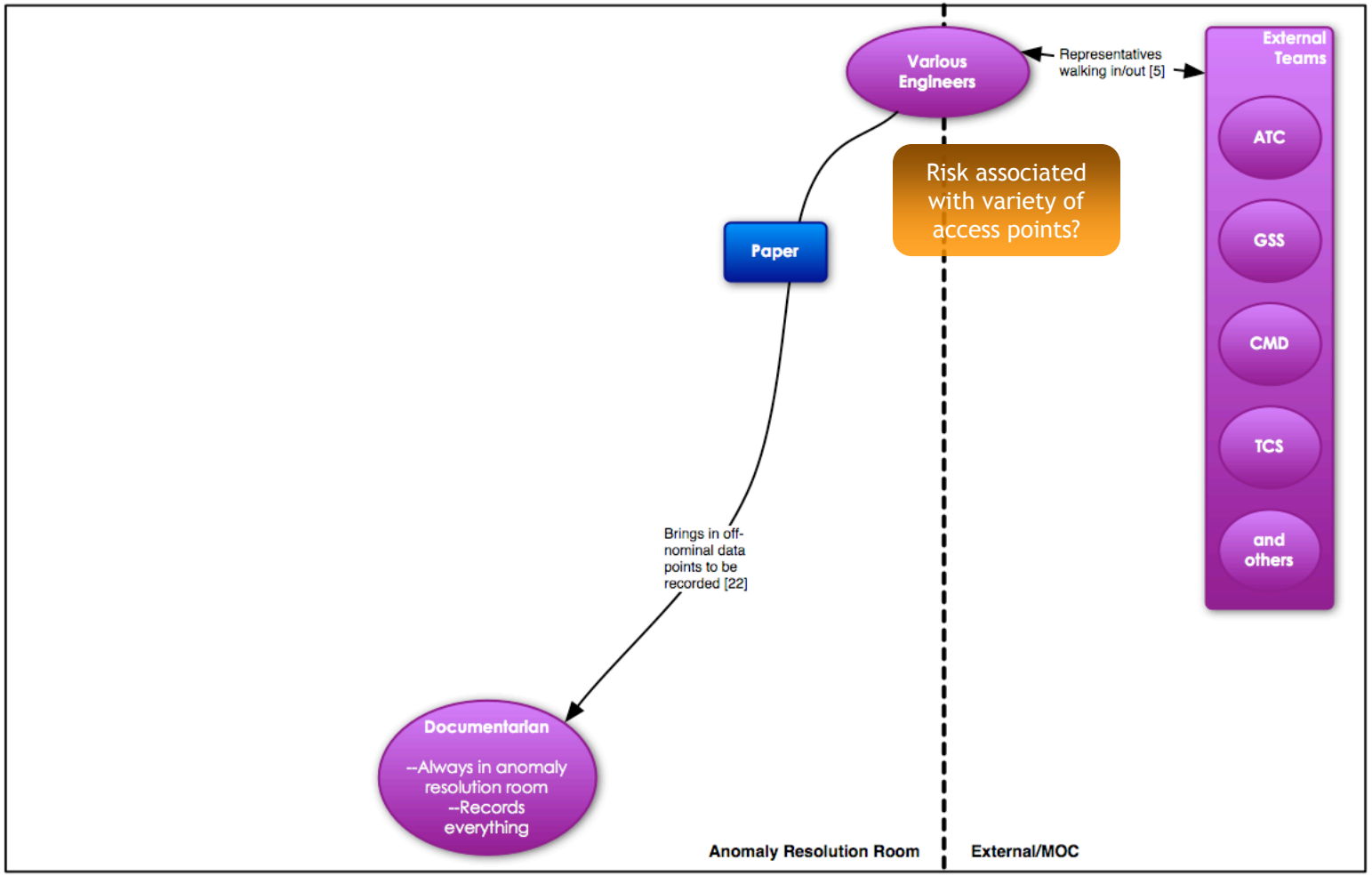
Complete Flow Model



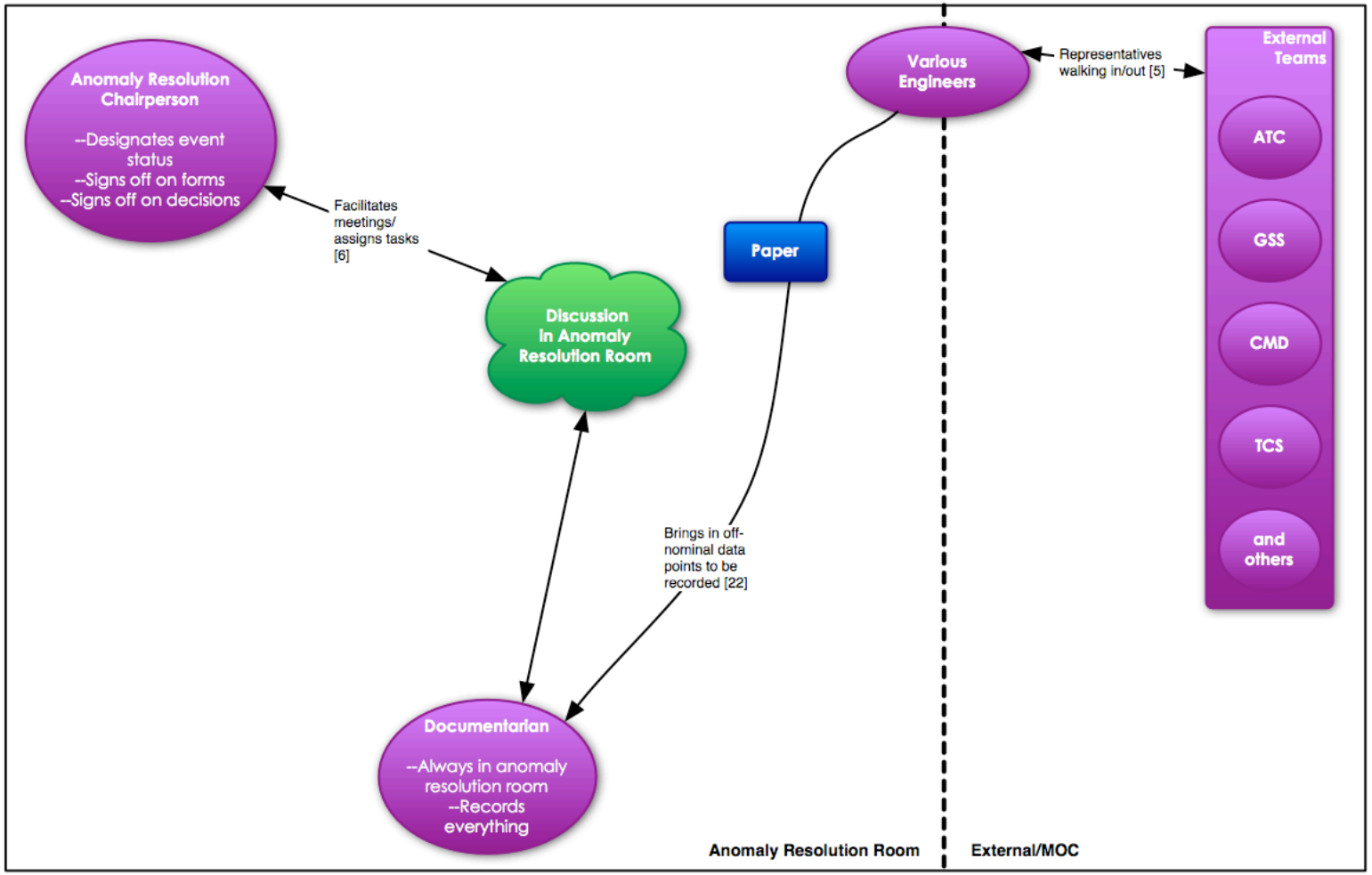
Sequence of Events

- Describe the processes chronologically
- Actions relate to intent
- Demonstrated on Flow Model

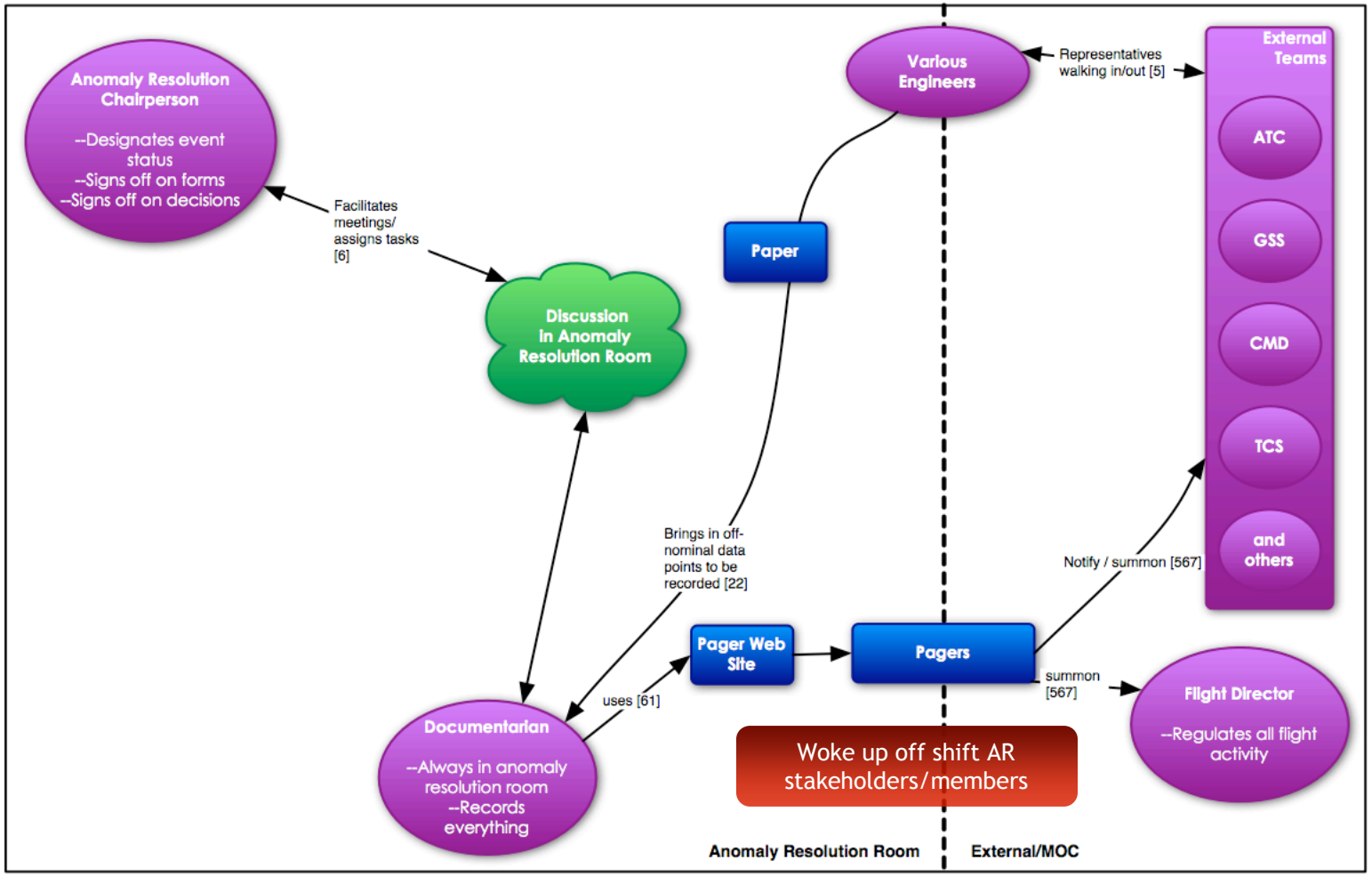
Sequence of Events: Anomaly



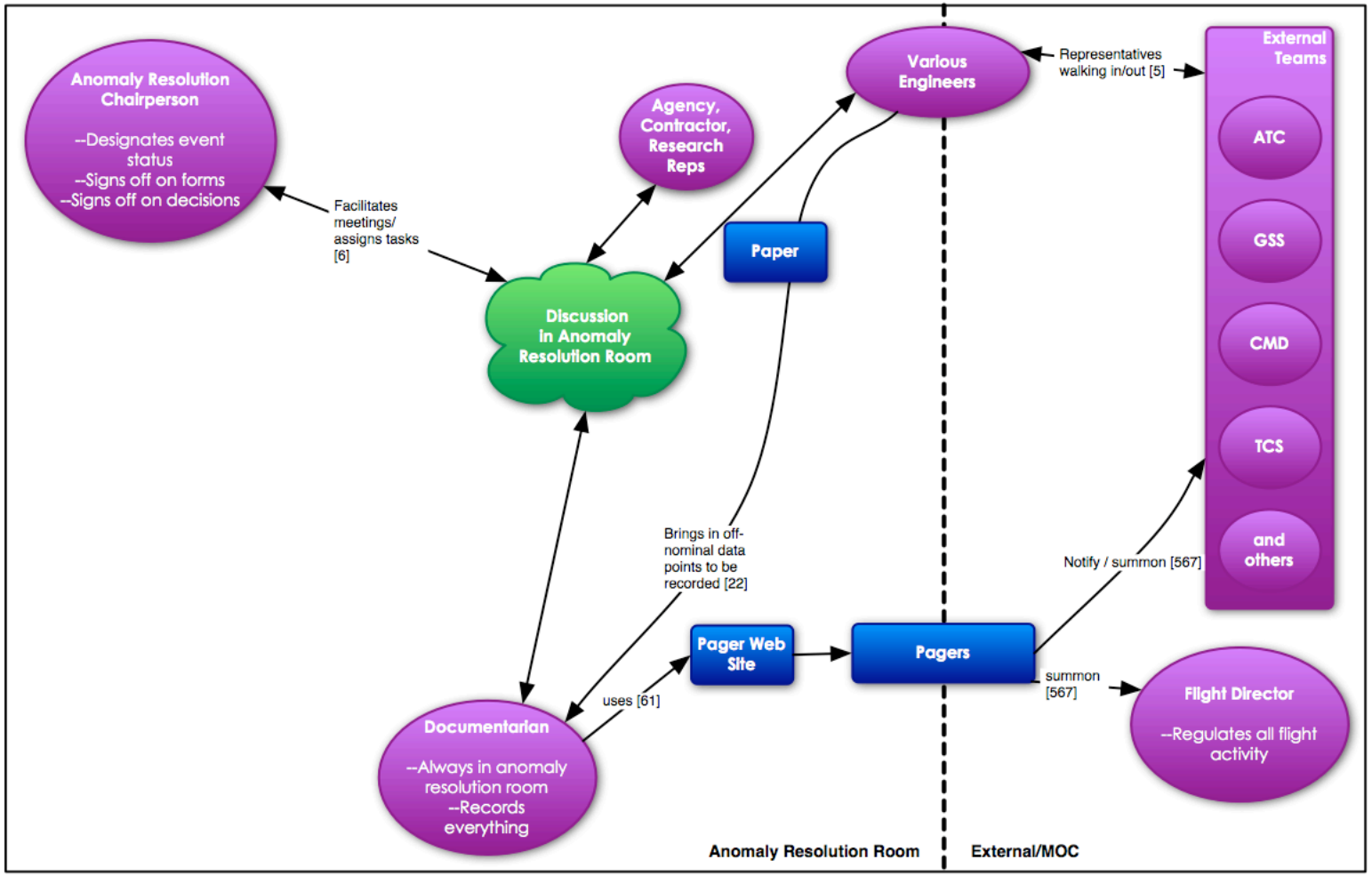
Sequence of Events: Anomaly



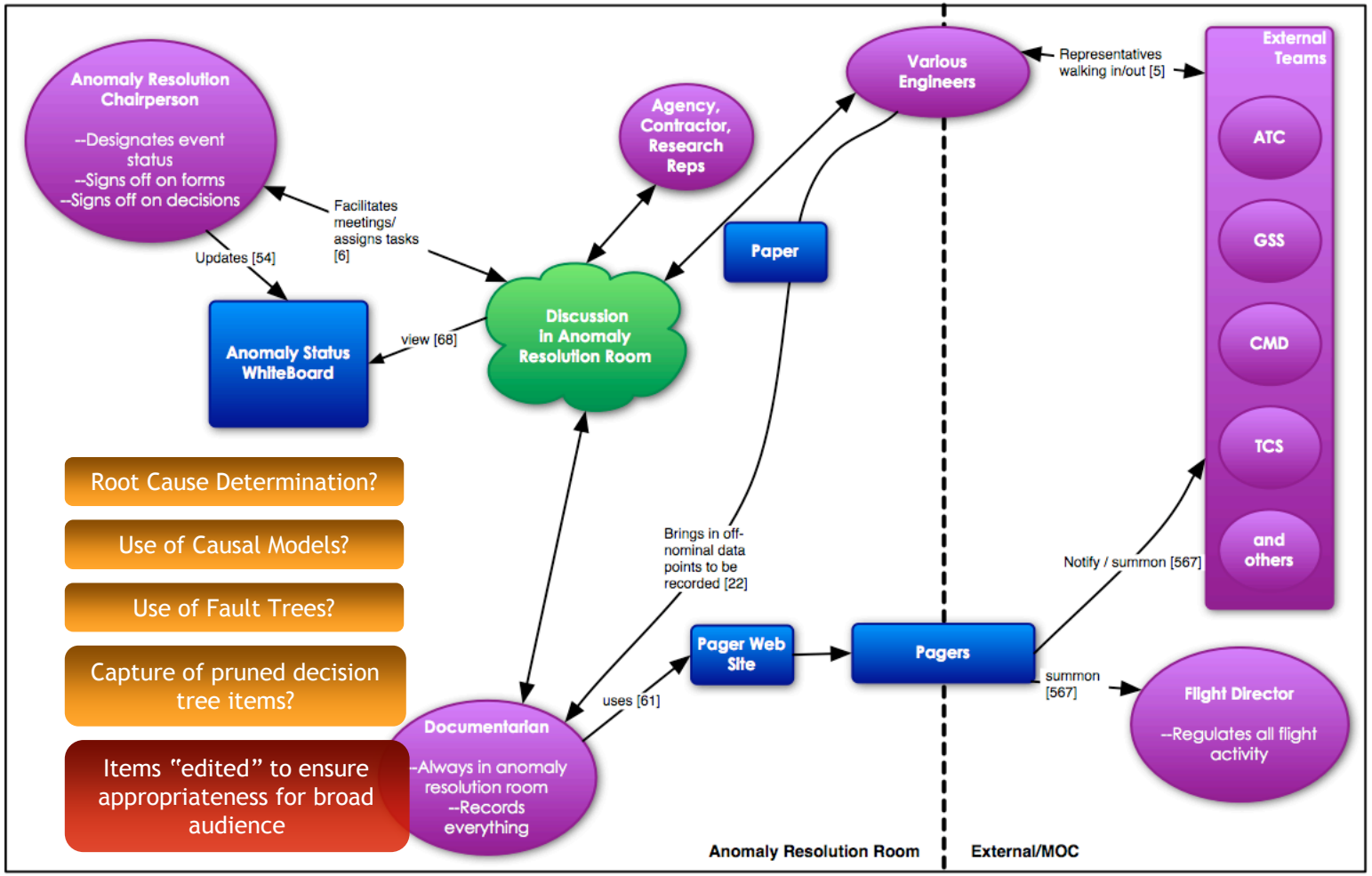
Sequence of Events: Anomaly



Sequence of Events: Anomaly



Sequence of Events: Anomaly



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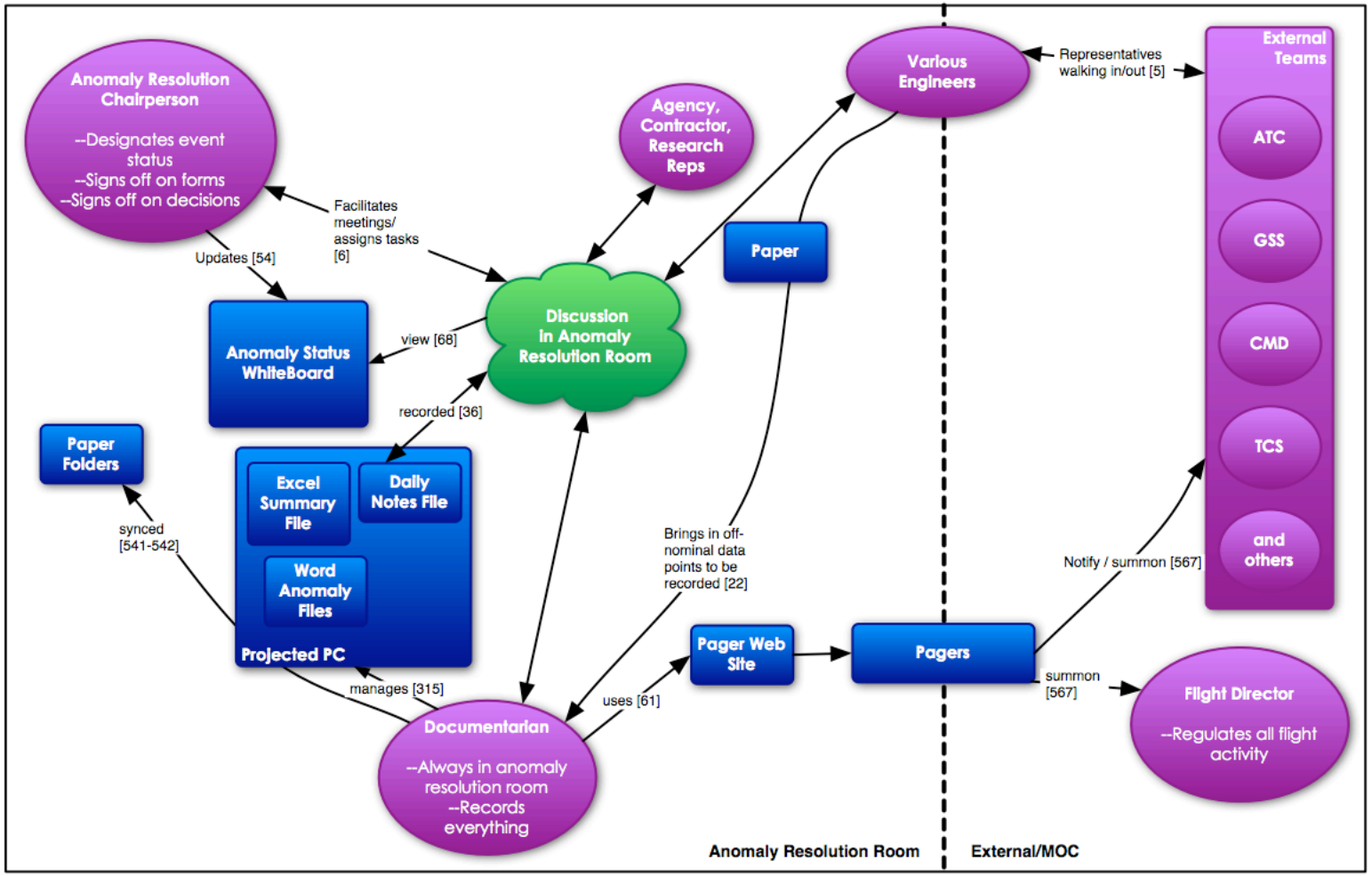
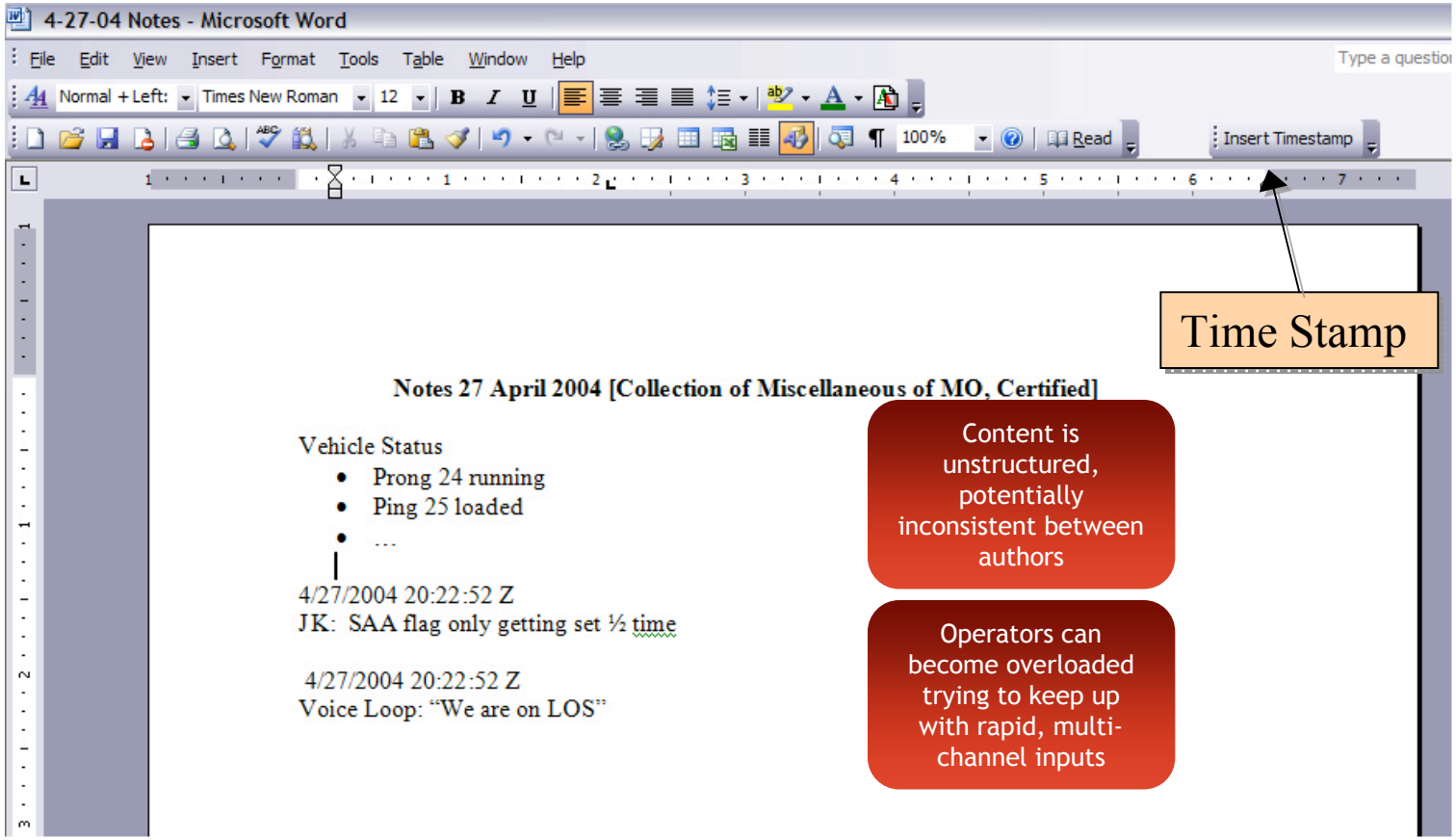


Work Products/Artifacts

- Artifacts are the tangible things that people create and use to help them do their work.
- Describes the structure and use of Artifact

Artifact: Daily Notes file



Artifact: Excel Spreadsheet

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Anomaly / Observation Event Summary

Page 1 of 2

#	Title	Description	Date / Time of First Occurrence	Owner	Severity	Resolution Status
OPEN Anomalies						
6	**Loss of com to FEP when loading Pong 2.**	**Loss of com to FEP when loading Pong 2.**	04/19/2004 03:30 Z	Team effort	**Major**	Cleared / Watch - Redlining procedure to disable automatic checks
OPEN Observations (items under evaluation - not formally declared as Anomalies)						
1	Pre-launch, possible leak in inner well pump-out valve (D-log at [redacted])	Pre-launch, possible leak in inner well pump-out valve (D-log at [redacted])	04/18/2004 23:36 Z	[redacted]	Obs	WATCH. Not launch constraint. Redundant valves and confirmed at least one valve was closed. The test on the other valve was not conclusive.
7	Guard Tank. Liquid Level Sensor Shows Downward Trend	PSL ([redacted]) reports seeing increase in downward trend in Guard Tank liquid level (3 samples - may be noise).	4/19/2004 14:56:25Z	[redacted]	Obs	Watch - decided to use as-is and proceded with turning off sensor. [redacted] to analyze data.
11	Inability to remotely reboot FEP	Inability to remotely reboot FEP	04/20/2004 00:30 Z	[redacted]	Obs	Cleared / Watch - box reset manually after change in port.
12	SWSI went down 3 times today	SWSI went down 3 times today	04/20/2004 01:35 Z	[redacted]	OBS	Watch requested by [redacted]

Doesn't reveal relationships between events

Only secondary data captured in the repository - no original data sources

Artifact: Excel Spreadsheet

printed on 4/20/2004 at 4:11 AM Z

Anomaly / Observation Event Summary

Page 2 of 2

#	Title	Description	Date / Time of First Occurrence	Owner	Severity	Resolution Status
CLOSED Anomalies						
CLOSED Observations						
2	Increased UIS power supply to ensure safe operations during power-up.	Increased UIS power supply to ensure safe operations during power-up.	04/19/2004 00:35 Z	[redacted]	Obs	Closed by [redacted] (AR[redacted] Chair). Decision: Turn off trickle charge during GMA ops. Analysis shows will be OK.
3	Thrust nullifier temp sensor not being read out	Thrust nullifier temp sensor not being read out	04/19/2004 00:53 Z	[redacted]	Obs	CLOSED - AR[redacted] meeting decided "Use-as-is."
4	Guard Tank may be greater than 55% full	Guard Tank may be greater than 55% full	04/19/2004 00:57 Z	[redacted]	Obs	CLOSED - AR[redacted] meeting decided no need to deplete guard tank.
5	AR[redacted] com loop failure	AR[redacted] com loop failure	04/19/2004 01:20 Z	[redacted]	OBS	CLOSED - [redacted] reset ports and fixed it.
8	SPRU temperature low - yellow	SPRU temperature is below yellow low limit but rising	4/19/2004 ~15:40Z	[redacted]	Obs	CLOSED (by AR[redacted] chair) - concluded temperature low due to AC working better than expected.
9	Copier on wrong circuit - blew breaker	Lost building power to Mission Planning & AR[redacted] areas	4/19/2004 16:22:31Z	[redacted]	Obs	CLOSED - Put copier on correct circuit
10	Residual Current on EPS High	Seeing 3 A (expected 1.7) due to SACE motor still driving closed	4/19/2004 17:15:32Z	Flight Ops	Obs	CLOSED - Launch scrub procedure was executed early (contrary to procedure), which interrupted launch load. Reviewed procedure and verified.
13	ECU red limit	ECU red limit	04/20/2004 02:54 Z	[redacted]	OBS	Closed - Incorrect limits in procedure. Limits corrected by [redacted]

Inadvertent use of the "move to closed" macro misclassified a group of anomalies

Artifact: Anomaly Whiteboard

#	Date/Time	Subject/Status	Team Leader
ANOM 5	4/20	ATC not correctly processing star tracker data	John Smith acquired stars after switch to sides
OBS 16	4/21	p9B SM Test activated	
ANOM 18	16:58 4/22	Back up to digital failed on gyro 2	
OBS 29	4/28	Station 200 temperature variation	
ANOM 49	5/17 13302	SM Activation high body rates	Porous Plug is choked

Hand managing content time consuming, error prone, and asynchronous

Actions poorly tracked in this representation

MAJOR

Cause in "Team Leader" field?

Early Process Requirements

- Staffing and Training
  - Train personnel to a sufficient level
  - Practice the anomaly resolution process before the start of the mission
  - Consider the role of leadership and design authoritative positions to work closely with the anomaly team
  - Design team and roles carefully and clearly and include a designated documentarian
- Design a process to systematically capture and store anomaly information
- Create a welcoming anomaly reporting environment
- Budgeting hardware, software and facilities resources appropriately

Early Design Requirements

- Have a single integrated encoding for information
  - Support searching across documents accurately by appropriate meta-data
  - Store documents with appropriate meta data and independent of operator accuracy or file structure
  - Make problem solving resources immediately accessible
  - Have an accurate, accessible and dynamic staffing schedule

Early Design Requirements

- Design a tool to systematically capture and store anomaly information
  - Use a tested and structured protocol to keep formal records of anomaly information (artifacts)
  - More formally capture products of discussion and analysis (for paths not taken) and follow up on anomalies after they are resolved
  - Capture organizational knowledge
  - Support tools that do not increase cognitive or operational workload

Early Design Requirements

- Enable situational awareness
  - Facilitate the distribution of information in an accurate, efficient and role-appropriate form
  - Enable efficient communication between remote and co-located team members
  - Carefully plan and publicize meetings
  - Track team member actions
  - Publish an accurate staffing schedule

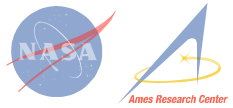
Design Constraints

- Must fit into existing nominal process to be useful during intense anomaly resolution situations

- Must span the boundary between anomaly and investigation phases

Next Steps

- Collect tool usage metrics (both ad hoc and new tool)
- Additional observation and interviews
  - L3/Ames (SOFIA)
  - Goddard Space Flight Center (Hubble)
- Iterative Prototyping



Thank You